REPORT NO. BPAD-863-4-15091R
DOCUMENT CONTROL NO. DC - 3583

TURBINE POW...
CONTROL VALVE ACTUATOR SYSTEM
MODEL NT-B4
PART NO. 2775004, SERIAL NO. 10

TEST DATA AND RESULTS (U)

CLASSIFICATION CHANGE

TO - UNCLASSIFIED [redacted]

By authority of AEC T.I.D. No. 1389-51 (ILDR Vol. 29, No. 1)

Changed by O. J. Seekheim Date 2/28/73

THE BENDIX CORPORATION
BENDIX PRODUCTS AEROSPACE DIVISION
SOUTH BEND 20, INDIANA

C66-3298

24

Contract No. NP-2
Under SNP-1

Report No. BPAD 863-4-15091R
Document Control No. DC-3583

TURBINE POWER CONTROL VALVE ACTUATING SYSTEM
BENDIX MODEL NO. NT-B4
PART NUMBER 2775004,
SERIAL NO. 10 (U)

TEST DATA AND RESULTS

August, 1963

Submitted to

Aerojet - General Corporation
Azusa, California

Prepared by
Aerospace Nuclear & Pneumatic Controls Department
Bendix Products Aerospace Division
South Bend, Indiana

Prepared Under
the Direction of: J. R. Doussard, Project Engineer

Approved by: A. J. Wetzel, Project Supervisor
NERVA Controls

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

INTRODUCTION

This report presents the results of the tests performed to evaluate the Turbine Power Control Valve Actuator, Model NT-B4, Part Number 2775004, Serial Number 10. All tests were conducted at the Bendix Products Aerospace Division of The Bendix Corporation, South Bend, Indiana, during June 1963. After testing was completed, the actuator was shipped to the Aerojet - General Corporation on June 28, 1963.

The testing included component evaluation tests, actuator performance tests at room temperature, actuator performance tests at low temperature, and final calibration before shipment.

Reproductions of actual actuator test data are included in this report.

SECTION II

COMPONENTS AND TEST RESULTS

2.1 MAGNETIC AMPLIFIER
(Part Number 179818, Serial Number 6)

A schematic diagram of the magnetic amplifier after system compensation is shown in figure 2-1.

2.2 TORQUE MOTOR
(Part Number 2151818, Serial Number 113)

Figure 2-2 shows the relationship between the differential current supplied to the torque motor coils and the flapper travel.

Figure 2-3 is a plot of amplitude ratio and phase shift versus frequency as observed during a frequency response test of this torque motor.

2.3 SERVO VALVE
(Part Number 2775104, Serial Number 12)

Figure 2-4 is a plot of the input flow to the servo valve versus valve spool position when the valve ports are exhausted to atmosphere.

Figure 2-5 shows the typical relationship of the dead-ended pressure measured at the servo valve ports and the valve spool displacement.

2.4 GEAR MOTOR
(Part Number 2150806, Serial Number 7)

Figure 2-6 is a typical plot of the output stall torque of this gear motor when the

gear motor is combined with the servo valve and the torque motor. Pneumatic gain adjustments were made on this combination by installing an 0.040 inch diameter bleed in the servo valve exhaust line and two 0.040 inch diameter bleeds in the gear motor ports.

Figure 2-7 is a plot of the no load speed of this combination versus the differential current supplied to the torque motor. The same pneumatic gain adjustment as described above was used during this test.

2.5 TRANSMISSION

(Part Number 2775005, Serial Number 3)

The following test data apply to this transmission:

Efficiency - 78.4%, at 1000 rpm with a 370 in.-lb. torsional load on the output shaft.

Efficiency - 76.8%, at 1000 rpm with a 740 in.-lb. torsional load applied to the output shaft.

Breakout torque - 1.5 in.-oz. as measured on the input shaft.

Backlash - not measurable on output shaft with 2 in.-lbs. of torque.

Stiffness - at increasing load of from 0 to 200 in.-lbs. on output shaft - 56,800 in.-lbs. per radian.

2.6 POTENTIOMETERS

(Part Number 2151097, Feedback Potentiometer, Serial Number 3D 5993, Instrumentation Potentiometer, Serial Number 3D 8594)

Both potentiometers have been tested at room temperature and at low temperature prior to installation in the actuator. Performance at room and low temperatures was satisfactory.

2.7 SWITCHES
(Part Number 2775305)

To avoid malfunctioning of the 28V DC switch circuit when the actuator output shaft is rotated more than 180°, the switches on this actuator have been wired in parallel instead of in series as on actuators previously shipped to the Aerojet-General Corporation. The switches on this actuator are set to close the circuit at 0.5 degrees from the zero position of the actuator when zero position is approached from the positive direction (decreasing the opening of the Turbine Power Control Valve).

2.8 THERMOCOUPLES

Four thermocouples have been installed in this actuator to facilitiate temperature measurements at various points through the actuator. The thermocouples used are Leeds and Northrup AWG No. 30 glass braided copper construction.

The thermocouples are located as shown in figure 2-8.

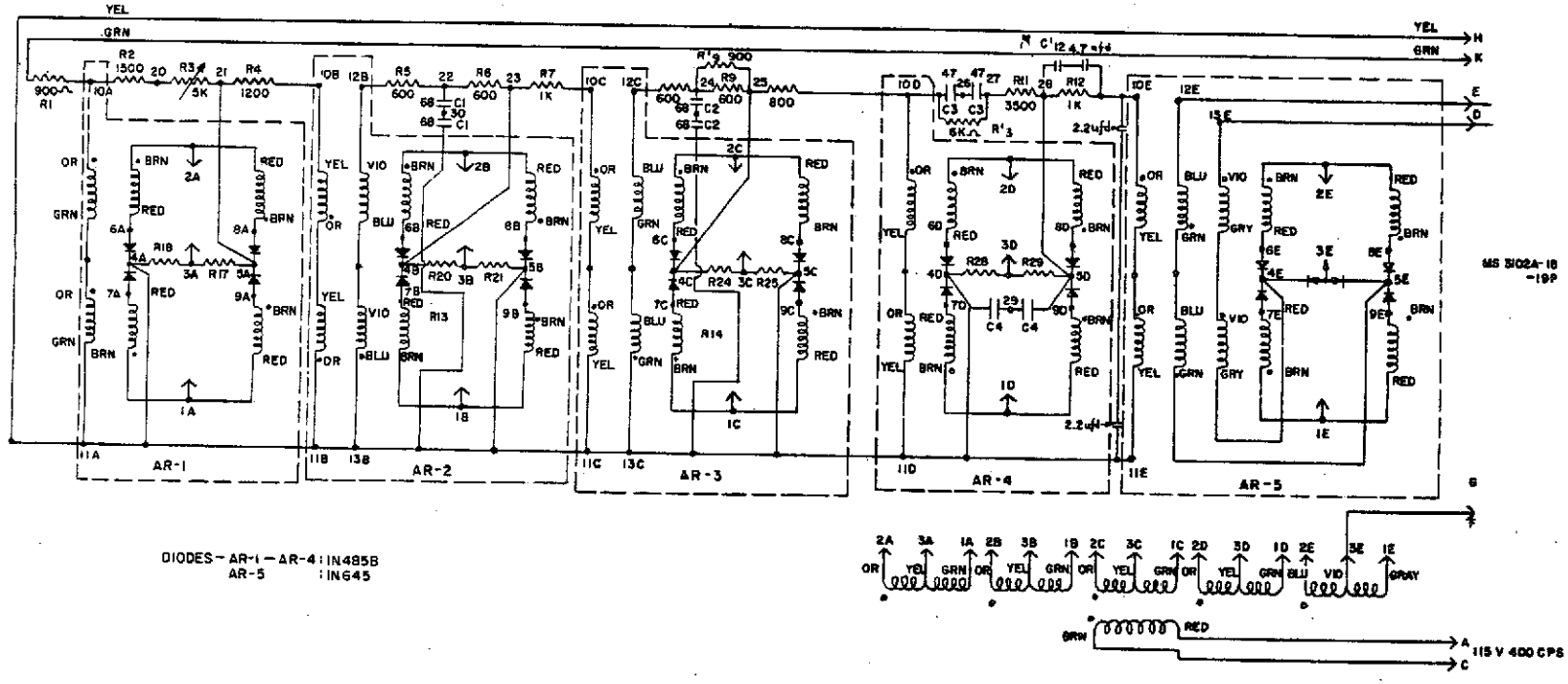


Figure 2-1. Schematic Diagram of Magnetic Amplifier

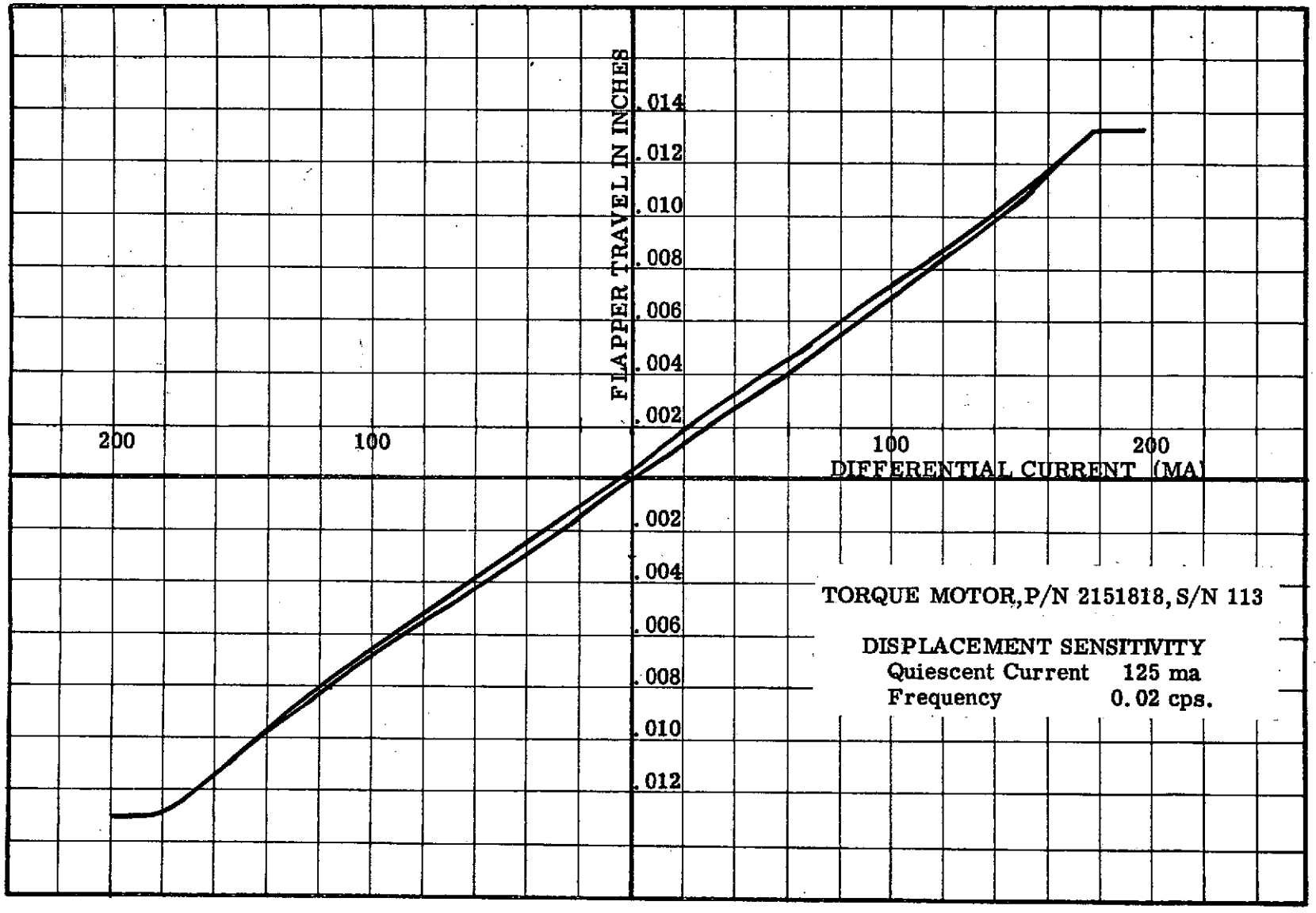


Figure 2-2. Differential Current Versus Flapper Travel

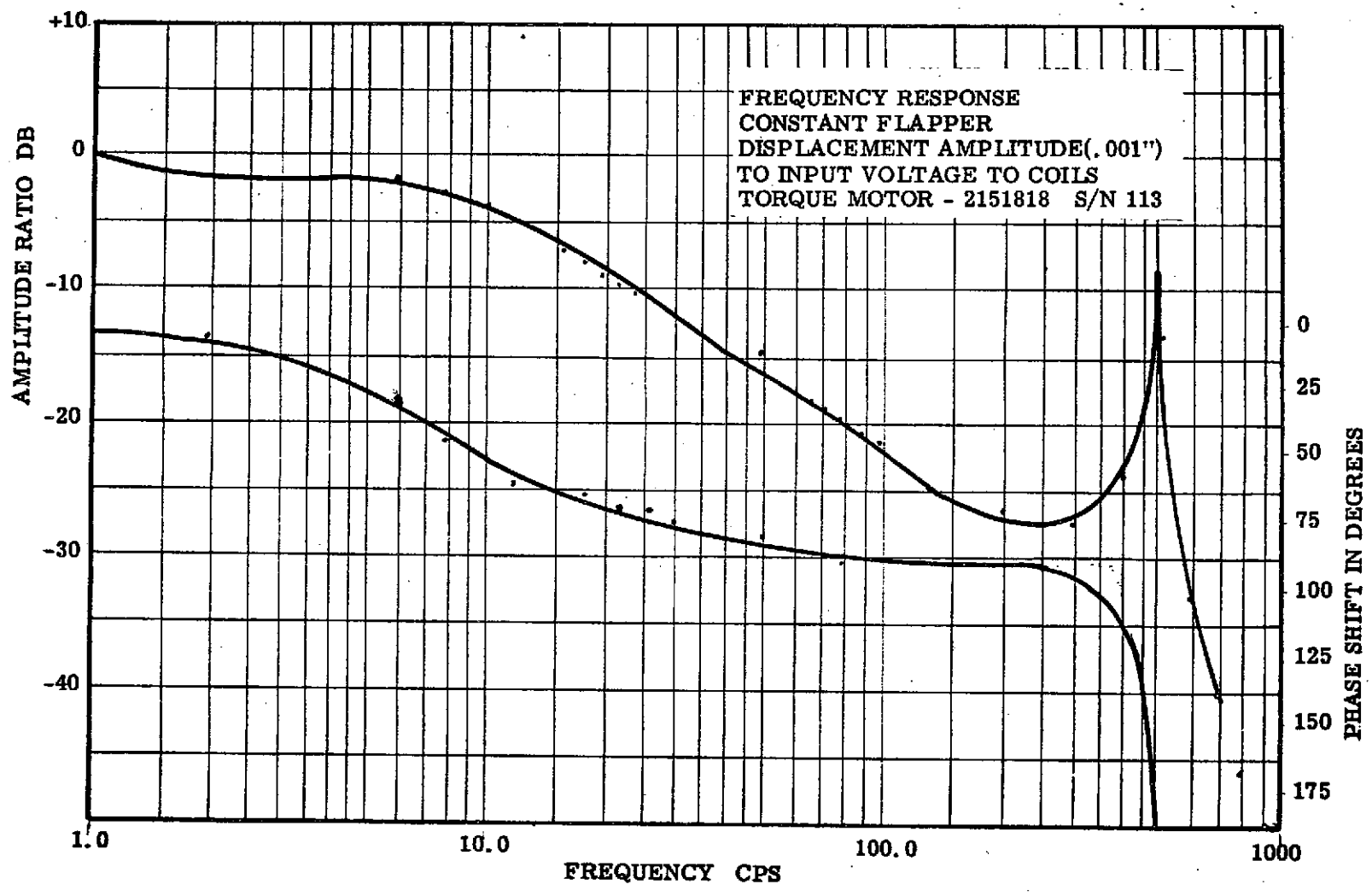


Figure 2-3. Amplitude Ratio and Phase Shift Versus Frequency

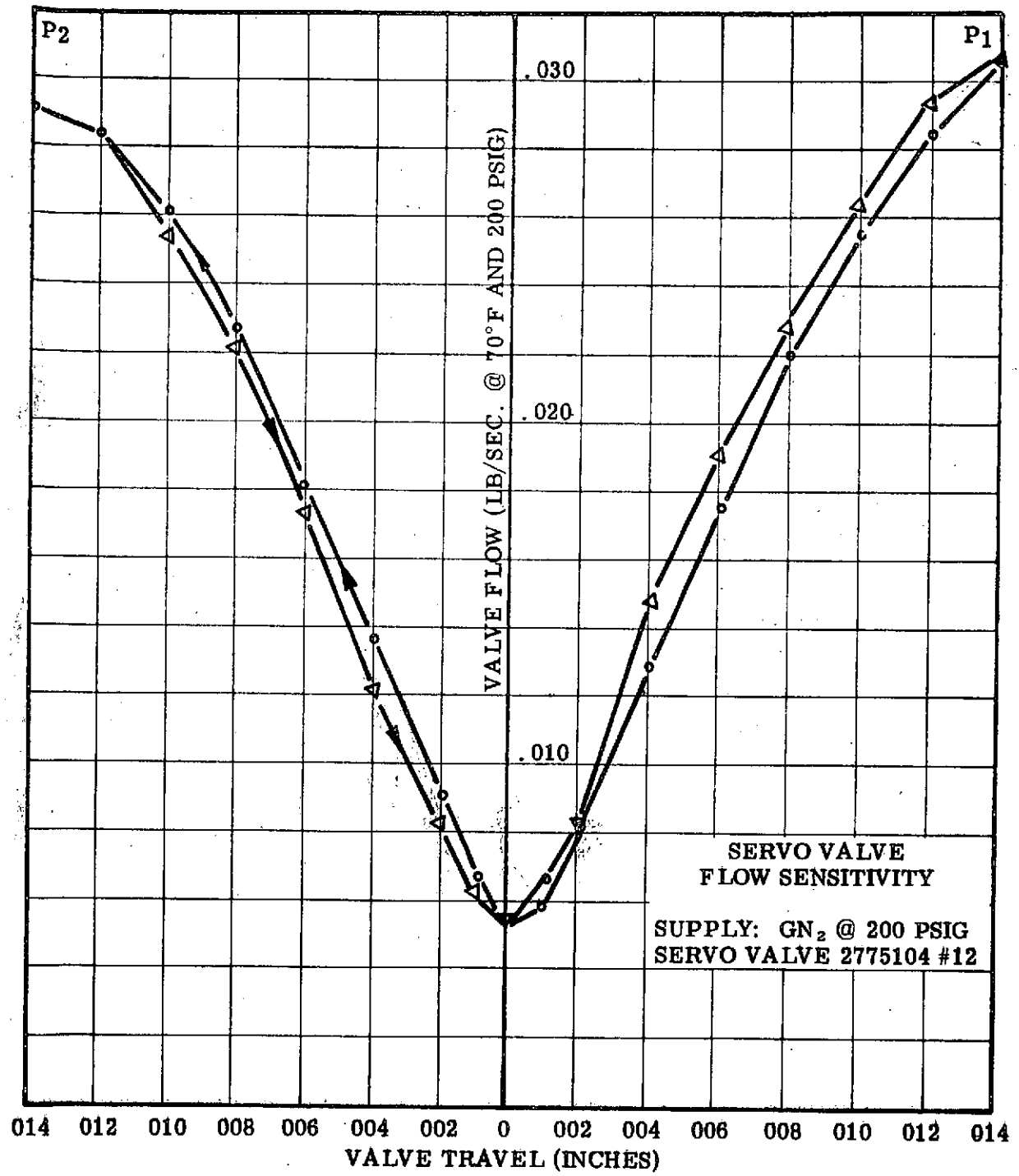


Figure 2-4. Dead-Ended Pressure Versus Differential Current

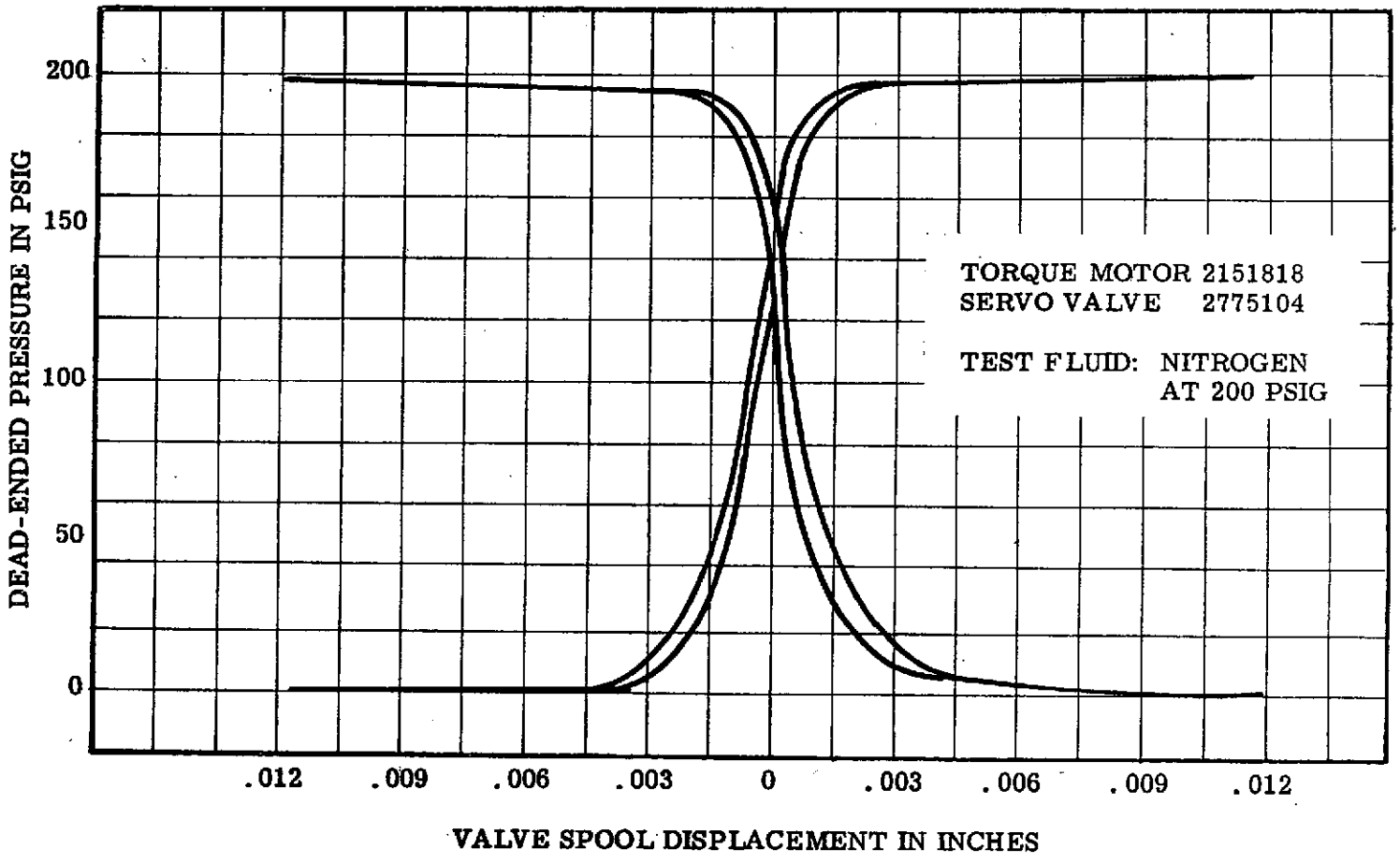


Figure 2-5. Input Flow-to-Servo Valve Versus Differential Current to Torque Motor

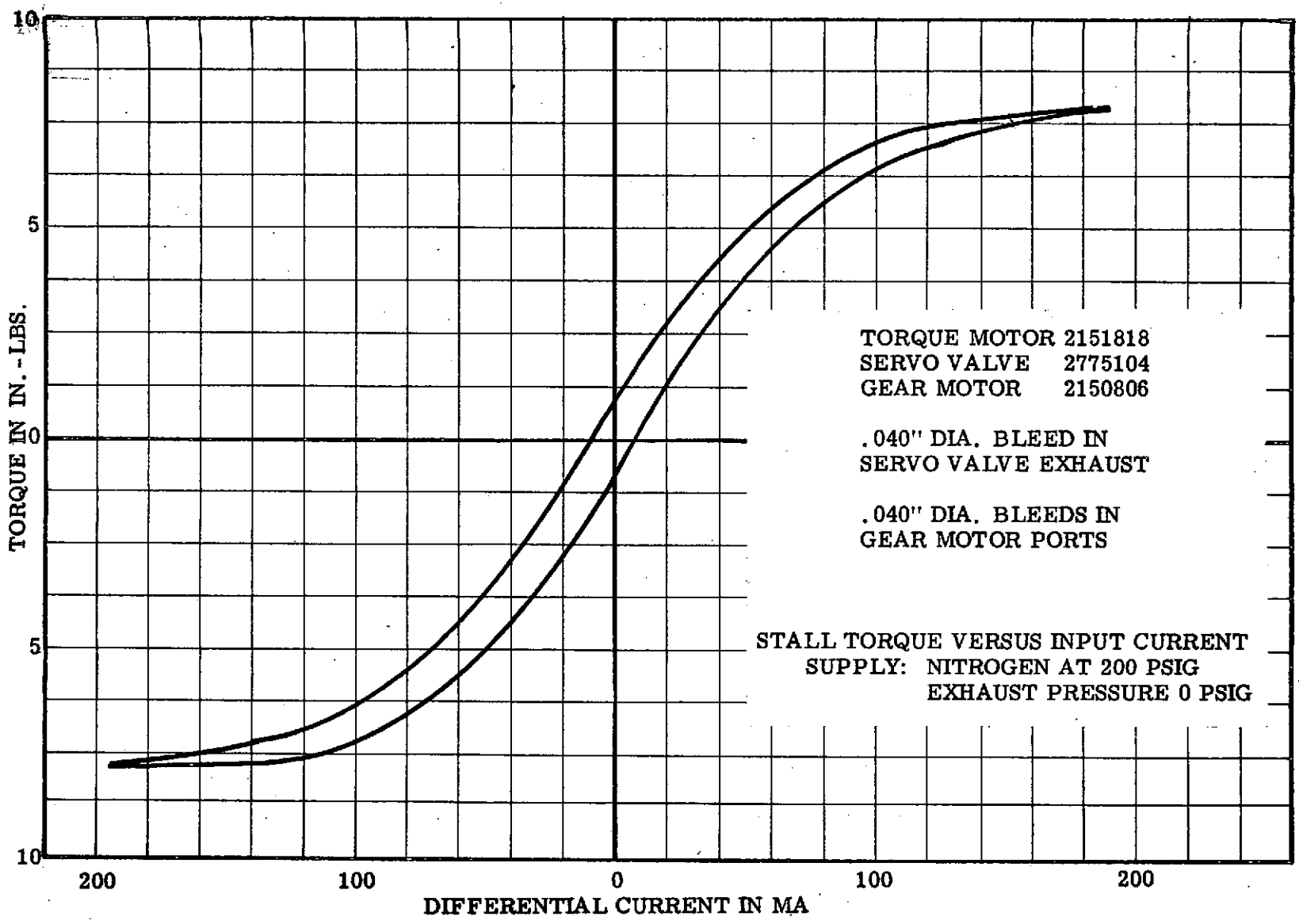


Figure 2-6. Stall Torque Versus Differential Pressure and Flow Torque Versus Differential Pressure

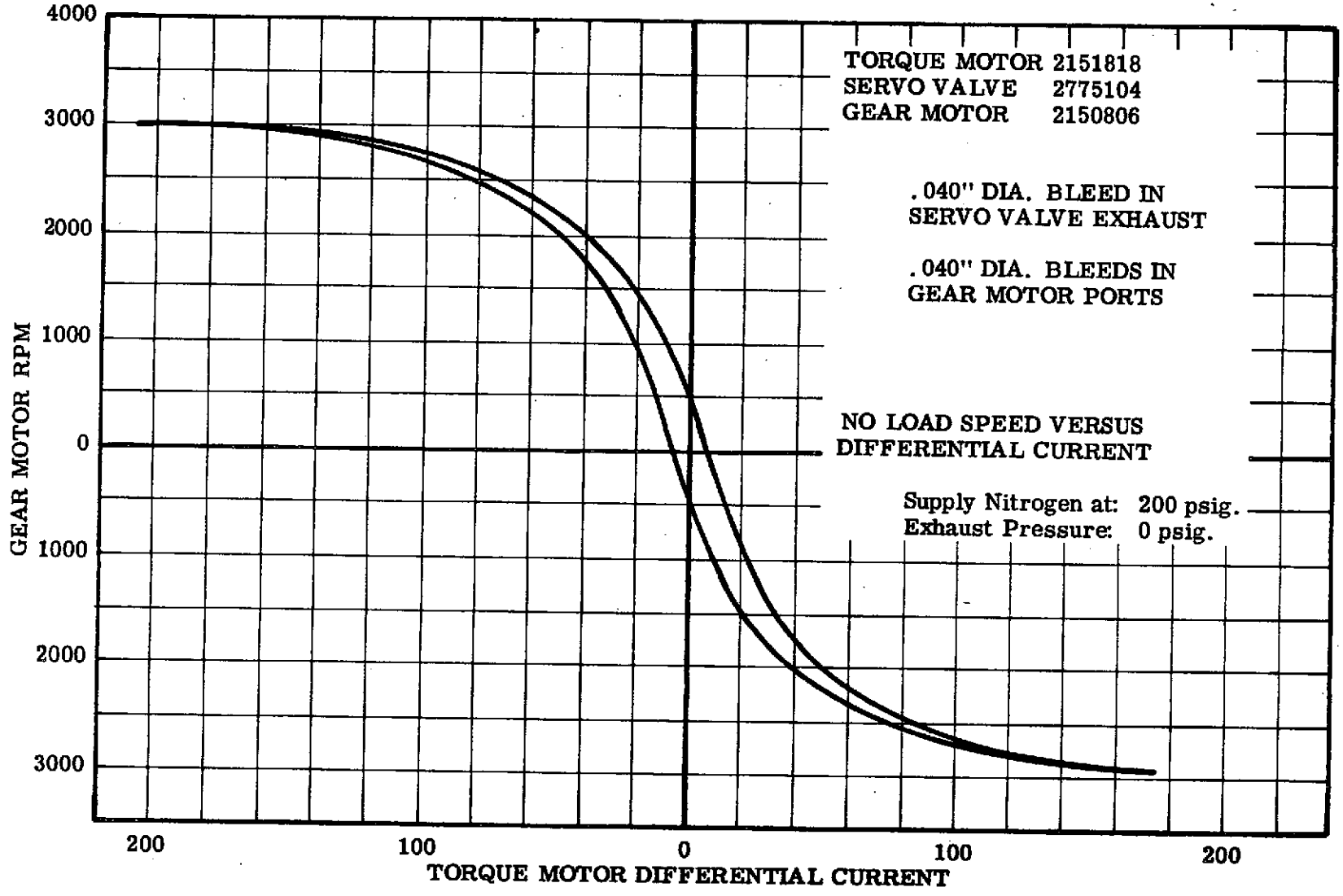


Figure 2-7. Stall Torque Versus Differential Current

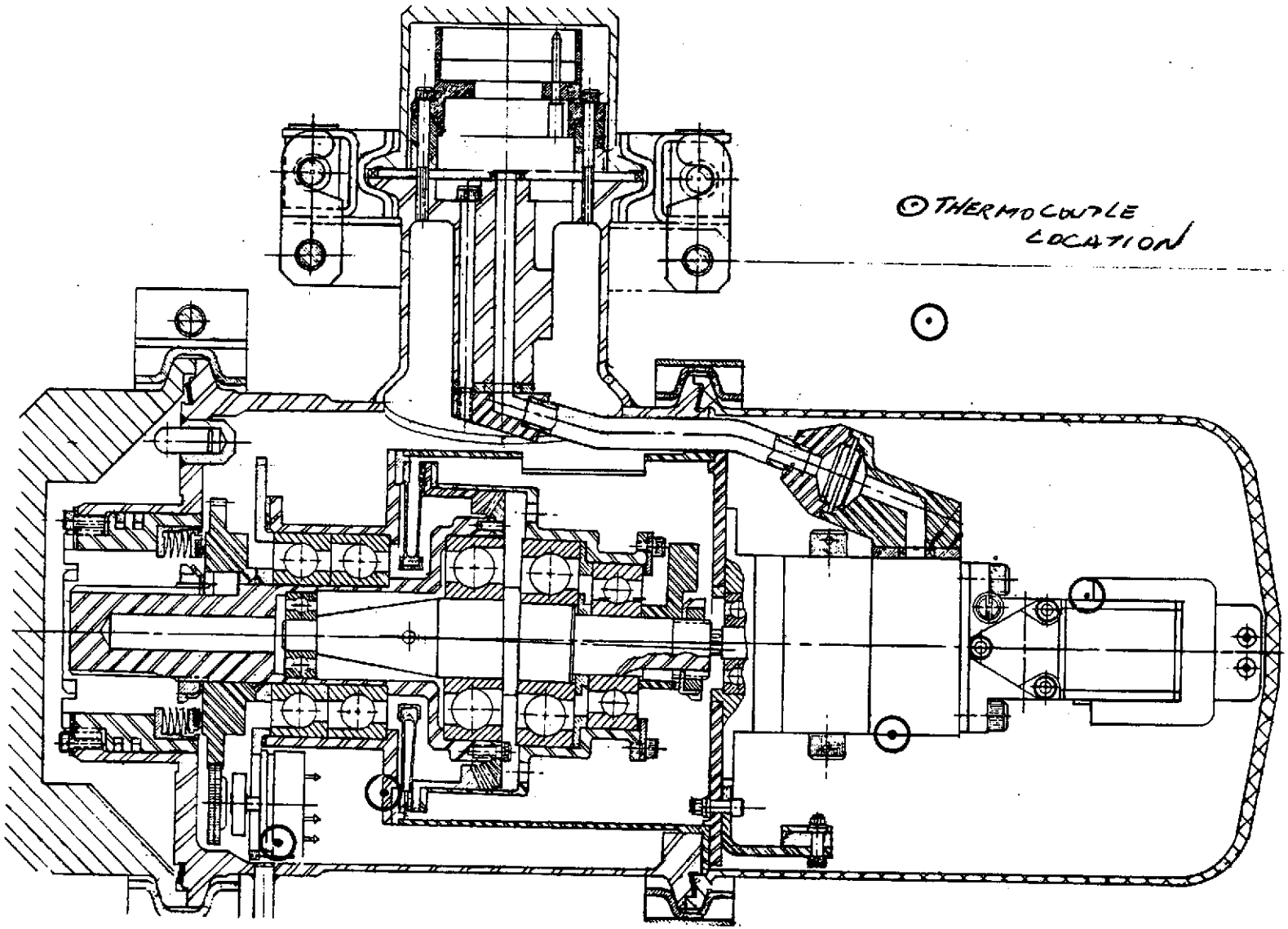


Figure 2-8. Motor Speed (RPM) Versus Torque Motor Differential Current (MA)

SECTION III

ACTUATOR TEST RESULTS

After all component testing was completed, the actuator was assembled and tested as a system. The actuator performance was compared to the performance criteria in Paragraph 3.1.

3.1 PERFORMANCE CRITERIA

3.1.1 Transient Response

The response of the actuator to an input step amplitude equal to 45 degrees from any actuator output shaft position greater than 5 degrees shall be such that 62 percent of the corresponding output level shall be achieved within 0.12 second. Following a transient disturbance to the input of the actuator, the overshoot of the output shaft motion shall not exceed 20 percent of the ordered output level and the output shaft position shall be restrained to within 5 percent of the ordered step within 0.3 second.

3.1.2 Slew Velocity

Under loaded conditions, the slew velocity shall be 360°/second minimum.

3.1.3 Dynamic Resolution

The resolution of the actuator shall be ±0.5 degree from the ordered position when the actuator is driven with a one-degree per second ramp at 0.05 cps. When coupled to the Turbine Power Control valve, the

resolution requirement is effective in the 5° to 90° actuator output shaft position range.

3.1.4 Frequency Response

The response of the actuator to a sinusoidal input signal of ±2 degrees amplitude shall approximate a second order system with a break point at a nominal 8 cps with a 0.5 damping ratio minimum.

3.2 ACTUATOR SYSTEM PERFORMANCE TESTS

Table 3-1 summarizes all the performance testing and test results obtained on the actuator system. The test conditions are shown in Table 3-2. Reproductions of the actual Sanborn recorder traces taken during the testing are shown in figures 3-1 through 3-6.

3.3 FINAL CALIBRATION BEFORE SHIPMENT

Before shipment, the actuator was recalibrated. Actual Sanborn recorder traces of these tests are reproduced in Figure 3-7.

3.4 TOTAL ACCUMMULATED TEST TIME

The total accummulated test time on the actuator assembly was 13.8 hours. Time accummulated on the individual components before they were combined into the actuator assembly was as follows:

Torque Motor, P/N 2151818, S/N 113 - 2.0 hours

Servo Valve, P/N 2775104, S/N 12 - 13.1 hours

Gear Motor, P/N 2150806, S/N 7 - 3.5 hours

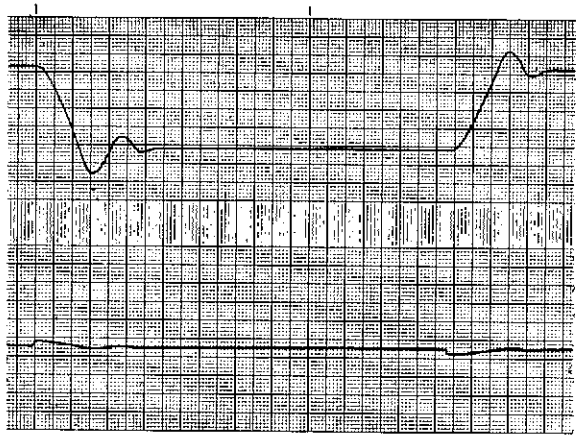
Transmission, P/N 2775005, S/N 3 - 1.7 hours.

Test	Test Condition	Forcing Function	Test Results	Figure Number
Transient Response	A	45° Step at 0.3 cps. around 42°	Overshoot: 29.5% 62% Rise Time: 0.10 sec. Settling Time: 0.28 sec.	3-1A
Slew Velocity	A	45° Step at 0.3 cps. around 42°	475°/sec. increasing angle 540°/sec. decreasing angle	3-1A
Dynamic Resolution	A	±5° Ramp at 0.05 cps. around 30°	Resolution ± 0.15 degree	3-1C
Dynamic Resolution	A	±5° Ramp at 0.05 cps. around 60°	Resolution ± 0.25 degree	3-1D
Static Resolution	A	0.1 cps, Sine Wave around 60°	Resolution ± 0.05 degree	3-1B
Frequency Response	A	±2° Sine Wave around 30°	90° Phase Lag at 11 cps. 180° Phase Lag at 22 cps.	3-2 3-3
Transient Response	B	45° Step at 0.3 cps around 42°	Overshoot: 16% 62% Rise Time: 0.11 sec. Settling Time: 0.27 sec.	3-4A
Slew Velocity	B	45° Step at 0.3 cps around 42°	400°/sec. increasing angle 370°/sec. decreasing angle	3-4A
Dynamic Resolution	B	±5° Ramp at 0.05 cps. around 30°	Resolution ± 0.20 degree	3-4C
Dynamic Resolution	B	±5° Ramp at 0.05 cps. around 60°	Resolution ± 0.25 degree	3-4D
Frequency Response	B	±2° Sine Wave around 30°	90° Phase Lag at 11 cps. 180° Phase Lag at 22 cps.	3-5 3-6

Table 3-1. Summary of Tests and Test Results

Test Condition	External Friction Load (In-Lb)	Torsional Spring Rate (In-Lb/Deg)	Shaft Seal Pressure (PSIG)	Actuator Exhaust Back Pressure (PSIG)	Gas Exhaust Temperature (°F)	Gas
A	0	2.67	650	45	81	Hydrogen
B	0	2.67	650	45	-267	Hydrogen

Table 3-2. Test Conditions

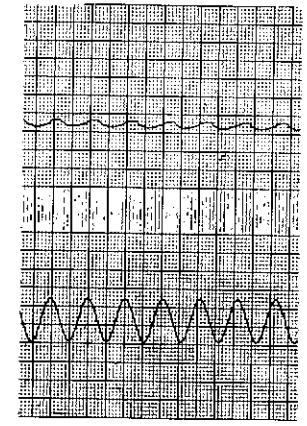


OUTPUT SHAFT POSITION: 2.0 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 42°

INPUT ERROR VOLTAGE FOR 45 DEGREE STEP

A. TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC.



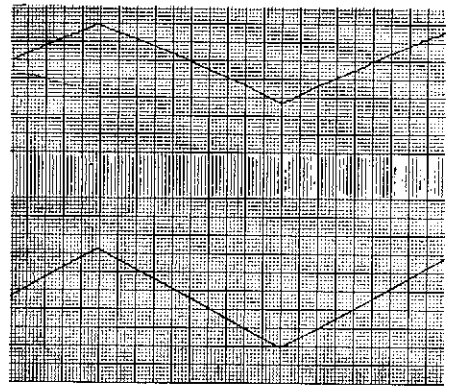
OUTPUT SHAFT POSITION: 0.01 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 60°

INPUT COMMAND SIGNAL: ±0.05 DEGREE 0.1 CPS SINE WAVE

B. STATIC RESOLUTION
PAPER SPEED: 1 MM/SEC.

Friction Load: 0 in.-lb.	Load Spring Rate: 2.67 in.-lb./deg.
Exhaust Pressure: 45 psig.	Gas: Hydrogen
Shaft Seal Pressure: 650 psig.	Gas Temperature: 81°F.
Supply Pressure: 200 psig.	

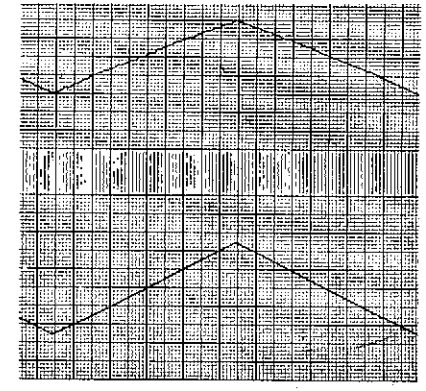


OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ±5 DEGREE RAMP AT 0.05 CPS.

C. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.



OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 60°

INPUT COMMAND SIGNAL: ±5 DEGREE RAMP AT 0.05 CPS.

D. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.

Figure 3-1. Closed-Loop Performance of TPCV Actuator (NT-B4, No. 10) Test Condition A

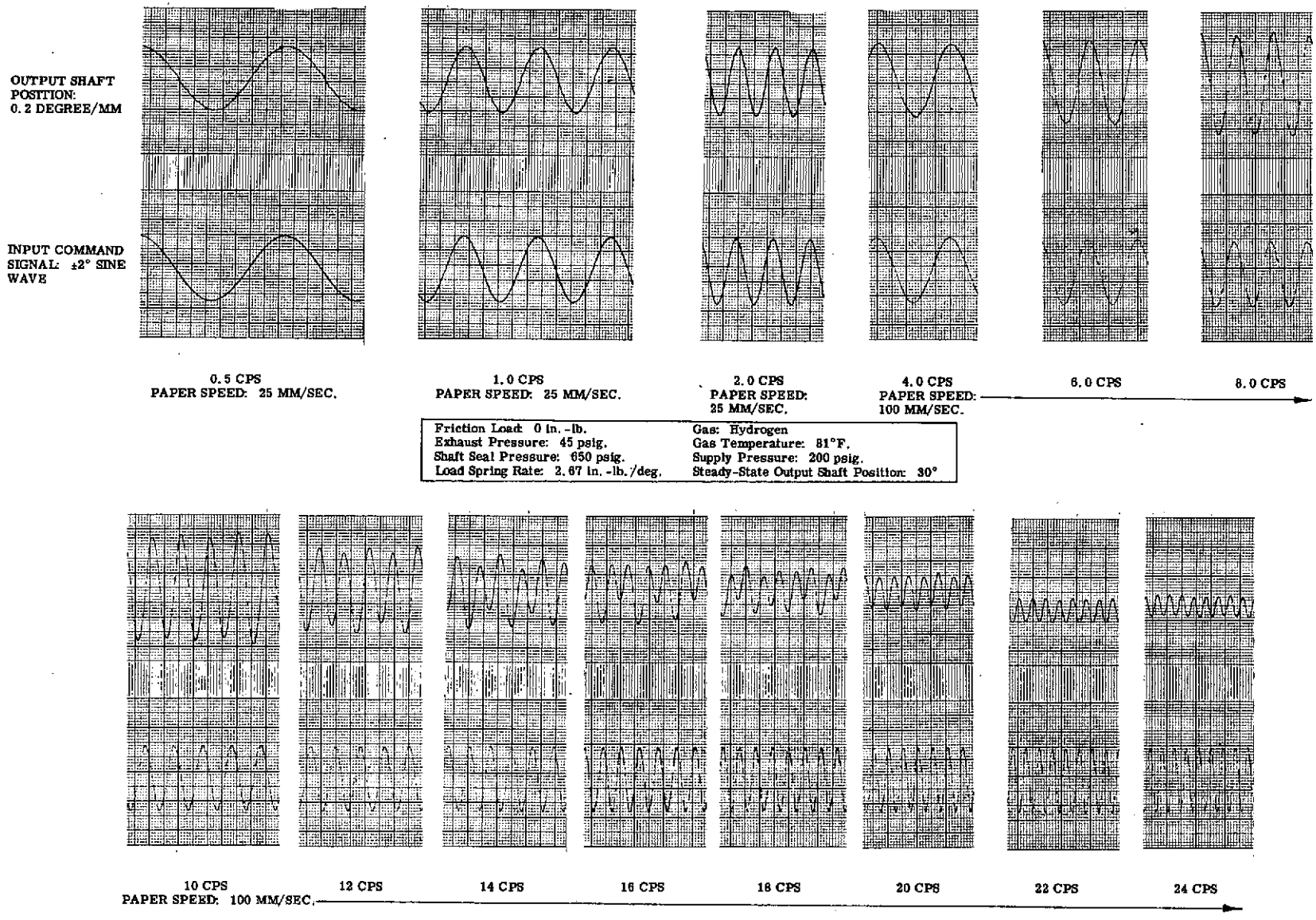


Figure 3-2. Frequency Response for Test Condition A

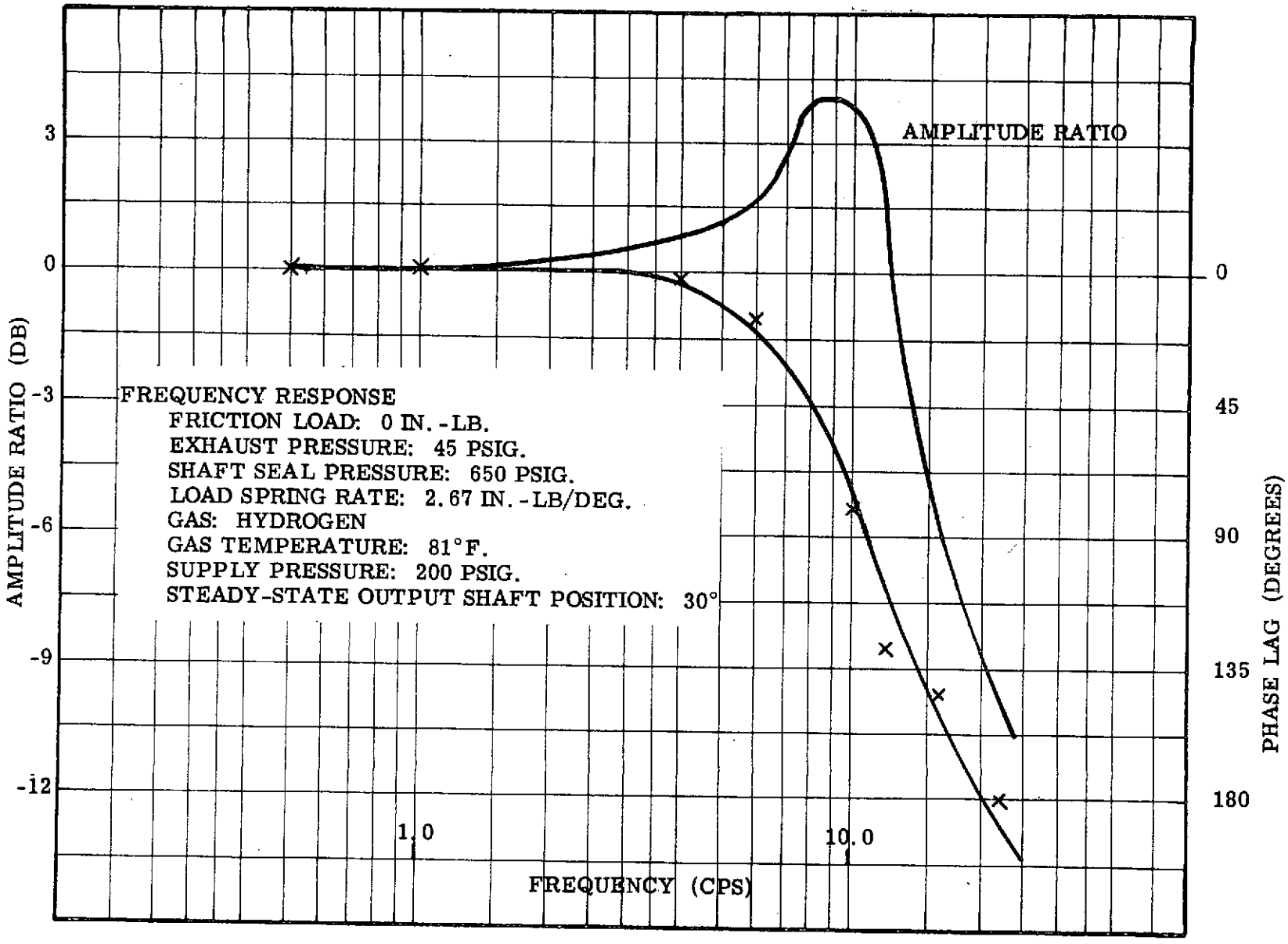
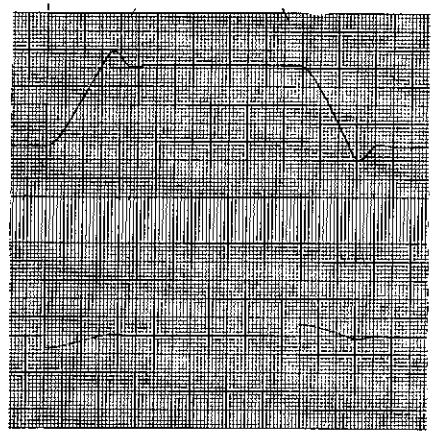


Figure 3-3. Frequency Response - Closed-Loop TPCV Actuator System at Room Temperature



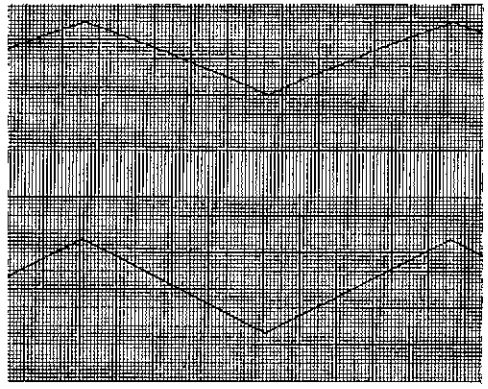
OUTPUT SHAFT POSITION: 2.0 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 42°

INPUT ERROR VOLTAGE FOR 45 DEGREE STEP

A. TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC.

Friction Load: 0 in.-lb.	Load Spring Rate: 2.67 in.-lb./deg.
Exhaust Pressure: 45 psig.	Gas: Hydrogen
Shaft Seal Pressure: 650 psig.	Gas Temperature: Exhaust - 267°F.
Supply Pressure: 200 psig.	

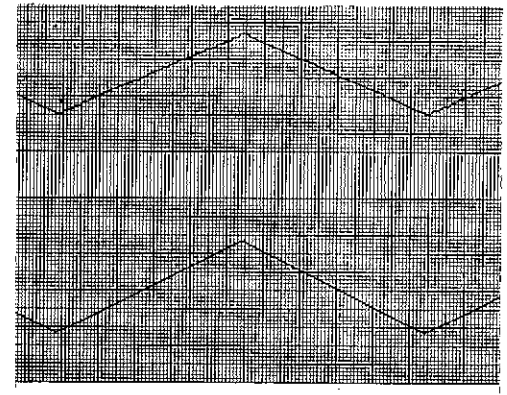


OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 30°

INPUT COMMAND SIGNAL: ±5 DEGREE RAMP AT 0.05 CPS.

C. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.



OUTPUT SHAFT POSITION: 0.5 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 60°

INPUT COMMAND SIGNAL: ±5 DEGREE RAMP AT 0.05 CPS.

D. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.

Figure 3-4. Closed-Loop Performance of TPCV Actuator (NT-B4, No. 10) Test Condition B

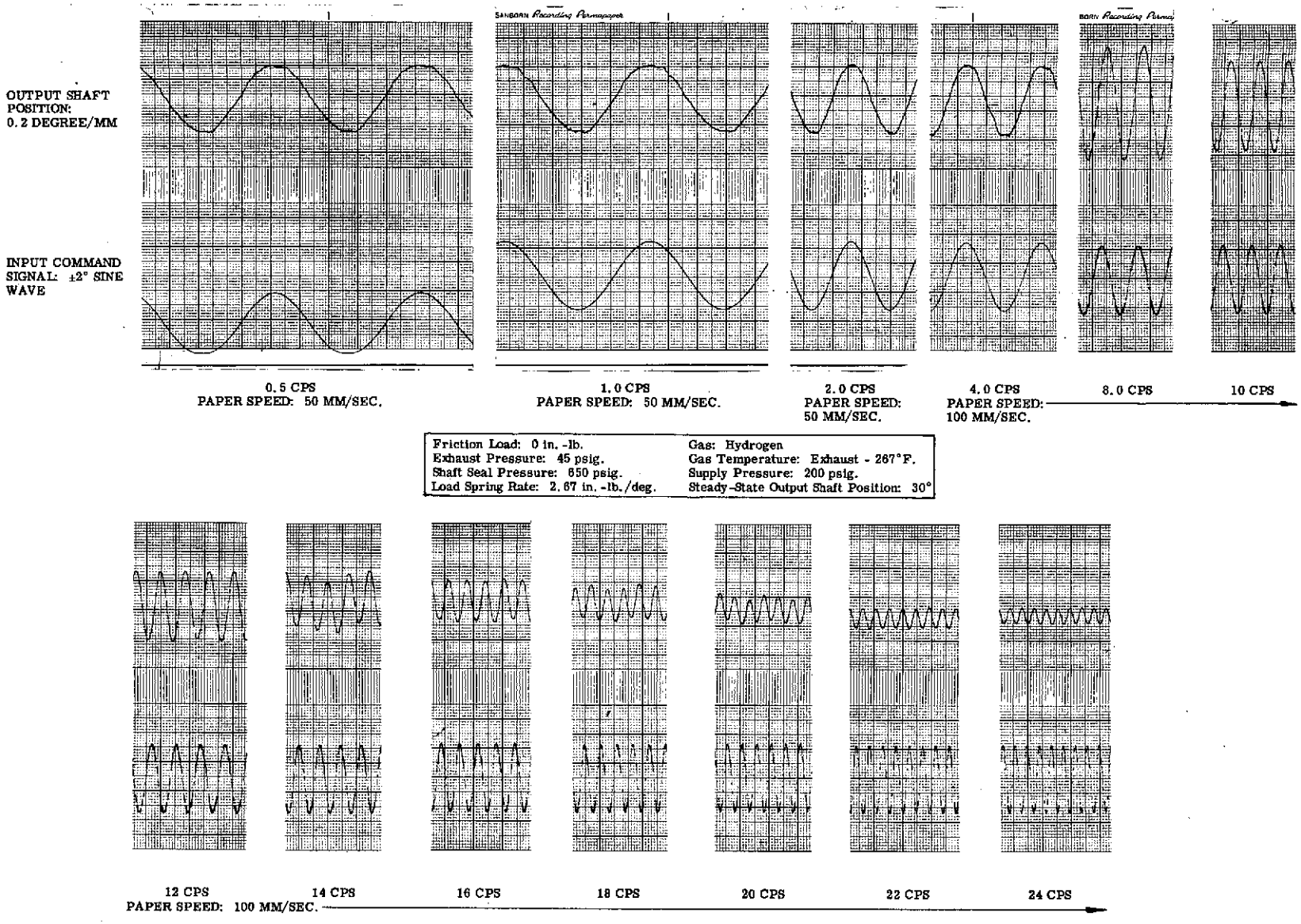


Figure 3-5. Frequency Response for Test Condition B

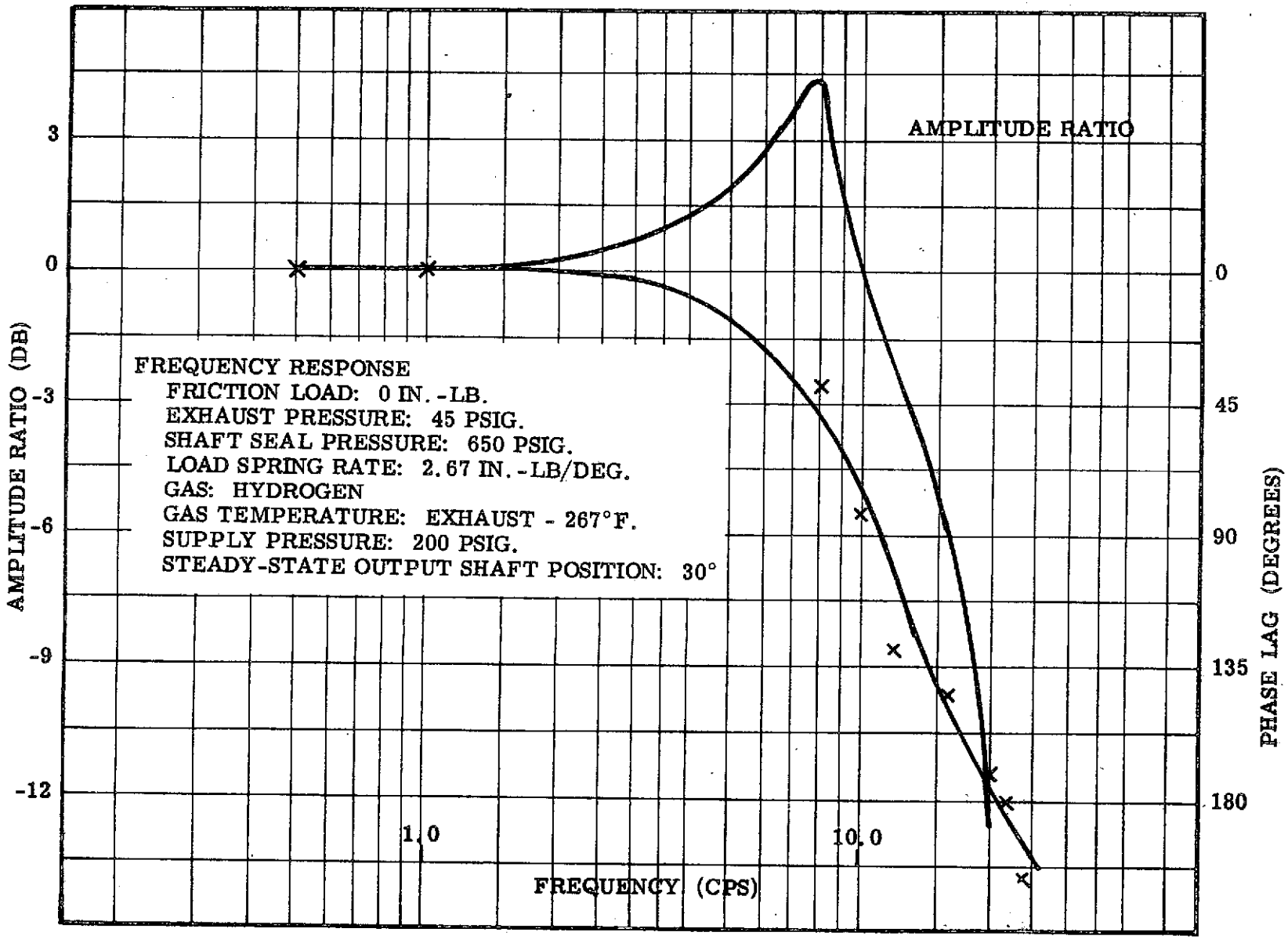
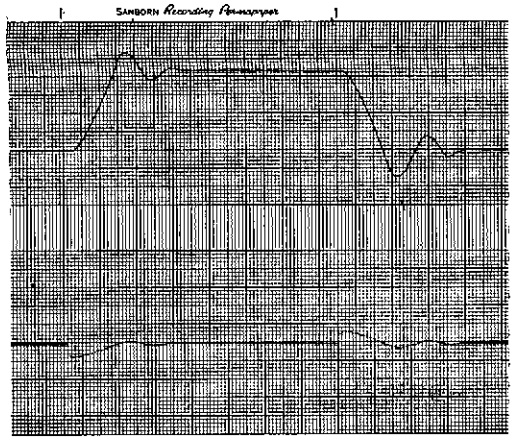


Figure 3-6. Frequency Response - Closed-Loop TPCV Actuator System at Low Temperature

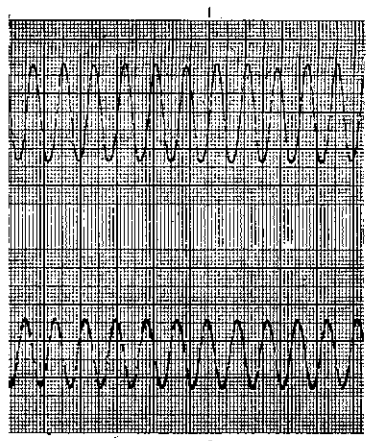


OUTPUT SHAFT POSITION: 2.0 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 42°

INPUT ERROR VOLTAGE FOR 45 DEGREE STEP

A. TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC.



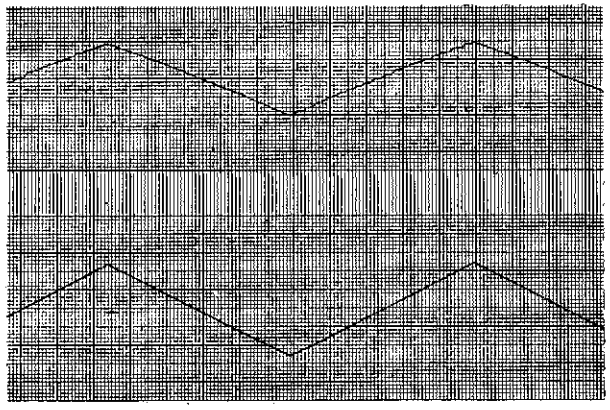
OUTPUT SHAFT POSITION: 0.2 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 60°

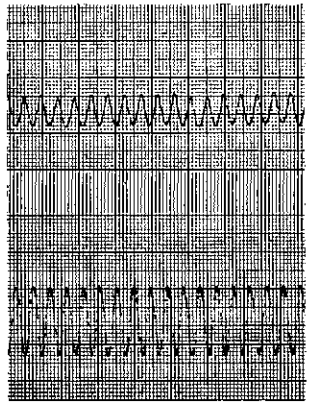
INPUT COMMAND SIGNAL: ±2 DEGREE SINE WAVE

B. FREQUENCY RESPONSE
90° PHASE LAG AT 12 CPS
PAPER SPEED: 100 MM/SEC.

Friction Load: 0 in.-lb.	Load Spring Rate: 2.67 in.-lb./deg.
Exhaust Pressure: 45 psig.	Gas: Hydrogen
Shaft Seal Pressure: 650 psig.	Gas Temperature: 84°F.
Supply Pressure: 200 psig.	



C. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.



OUTPUT SHAFT POSITION: 0.2 DEGREE/MM

STEADY-STATE OUTPUT SHAFT POSITION: 60°

INPUT COMMAND SIGNAL: ±2 DEGREE SINE WAVE

D. FREQUENCY RESPONSE
180° PHASE LAG AT 22 CPS.
PAPER SPEED: 100 MM/SEC.

Figure 3-7. Final Calibration Data